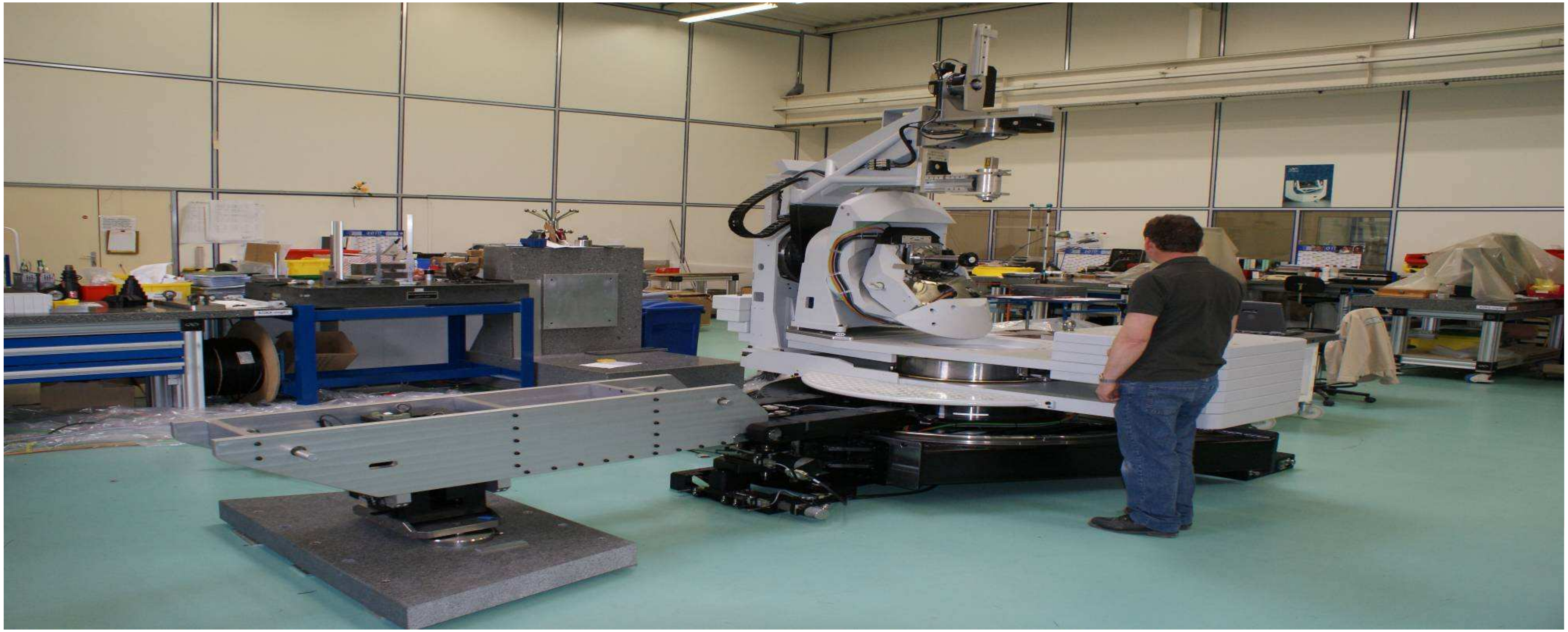
# Fine, fast and coordinated motion and its controls



*Diffractometer Soleil Sirius beam line*

**Jean VILAIN**

X-Ray application manager

Precision Motion Products & Services

## Summary

- WHY?
- Coordinate system
- Scan Modes differentiation
- On-the-fly data acquisition requirements
  - Input
  - Output
  - data
- On-the-fly data acquisition and trajectory requirements
  - Mechanical
  - Motion controller
- X-Ray Diffraction Road Map
- Conclusion

- WHY?

  – Drive a better adapted system (kappa geometry) with a classical referential (Eulerian geometry)

  – Save time to run Scans from hours to minutes

  – Improve resolution and scan finesse.

# System control command can change the coordinate system used such as:

## Kappa block and circle

In the Kappa geometry the Eulerian Chi rotation is accomplished by a compound motion of Kappa and Omega. The range of motion of Kappa and Omega for a given Chi depends on the angle between the Kappa axis and the Omega axis Alpha. An Alpha of 45° is the smallest angle that will allow the Phi axis to rotate through a Chi of 90°. Increasing Alpha above 45° is beneficial in that it reduces the range of motion of Kappa and Omega needed to achieve a given Chi angle. Kappa and Omega depend on Alpha and Eulerian Chi through:

$$\kappa = \arcsin\left(\frac{\sin\left(\chi/2\right)}{\sin(\alpha)}\right) \qquad (1)$$

$$\varpi = \arccos\left(\frac{\cos\left(\kappa/2\right)}{\cos\left(\chi/2\right)}\right) \qquad (2)$$

Figure 5 shows the range of motion of Kappa and Omega versus Chi for different Alpha's. The down side of increasing Alpha is that it increases mechanical interference. In choosing an Alpha angle a balance between the two competing effects must be reached. Though a somewhat arbitrary dividing line it seems that an Alpha of 50° represents the best compromise.

The Phi circle connects to the Kappa circle through the Kappa block. The Kappa block should be rigid enough so that it contributes negligibly to the sphere of confusion (SOC), when a 10 kg load is applied halfway between the center of the Phi circle and the diffractometer center symmetric about the Phi axis and for the full range of Kappa rotation. The Kappa block and the counterweight for the Kappa circle shall not project into a 50mm radius cylinder centered on the x-ray beam axis (see Figure 4a) for Kappa rotated +/-90 with Omega and Psi set to zero. This gap provides room for flight paths, slits, additional optics, and normalization detector. The Kappa block shall have a wire route to accommodate wiring for the stages mounted above it as well as additional space for future sample specific wires. Since the torque on the Kappa circle worm gear depends on the sample load and angle settings the Kappa circle shall have an on axis incremental encoder to eliminate the loss in angular accuracy that a shaft encoder alone would introduce.

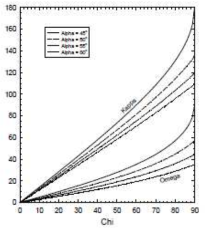


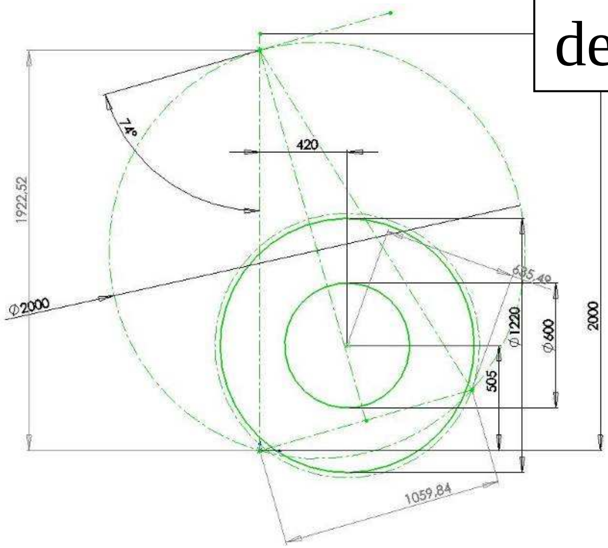

**Figure 1. Motion of Kappa and Omega as a function of Eulerian Chi for different inclination angles Alpha.**

Convert Eulerian geometry into Kappa geometry

Kappa Diffractometer
(DIAMOND I16 beam line)

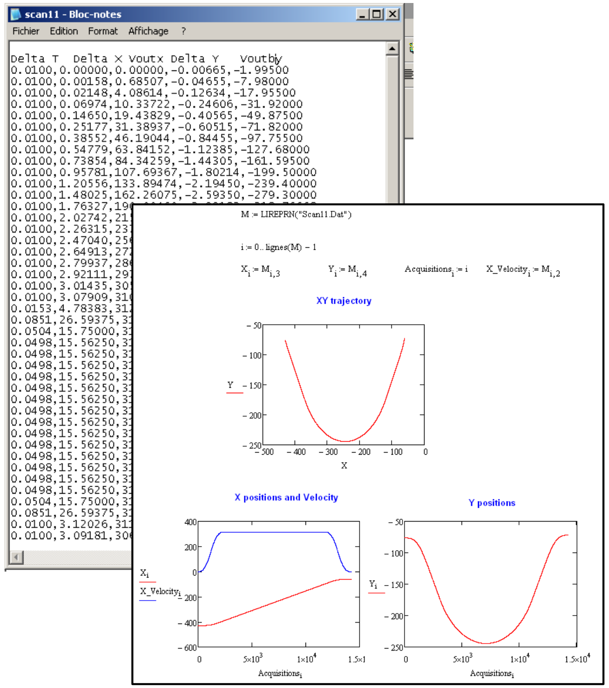
# Fine, fast and coordinated motion and its controls

Convert R-theta system into classical circles for De Rawland geometry and allows compact design




De Rawland Spectrometer
(SOLEIL, GALAXIES beam line)

# Fine, fast and coordinated motion and its controls




Convert linear motions into rotary motions for long distance detector/sample or for Ultra precision system in nano-focus beam line (air-bearing system)

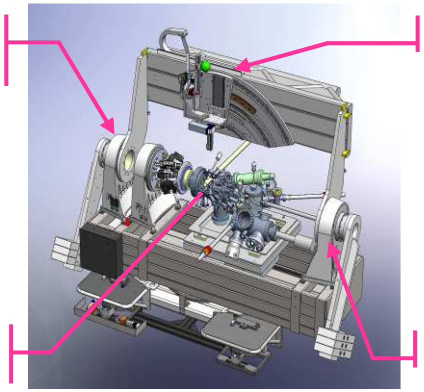
ESRF

# Fine, fast and coordinated motion and its controls

Create a gantry system for large volume sample environmental chambers

Theta-1 circle

Gamma Circle



UHV Chamber and diagnostic devices

Theta-2 circle

Diffractometer for Ultra High Vacuum applications (SOLEIL, SIXS beam line)

## Diffraction scan mode differentiation on complex trajectories

Complex scan trajectories can be done in step by step mode or in a continuous mode

- Step by step scan mode
  - Easiest way to scan but due to the step and settling the scan is long to perform
    - Long term stability of the environment become a physical problem (drifts, temperature)
    - Gathered data are less reliable
  - Limits the scan sampling data acquisition size (proportional to the time spent)
  - Efficient for simple scans and low photon rate

- Continuous mode
  - Very fast scans bring all the advantages generated by short term stability
  - Brings a better and natural finesse to the scans with nearly infinite size data files
  - Scans can be simulated before their execution
  - Economics (less beam running time for more experiments)
  - Requires a high dynamic system

# Fine, fast and coordinated motion and its controls

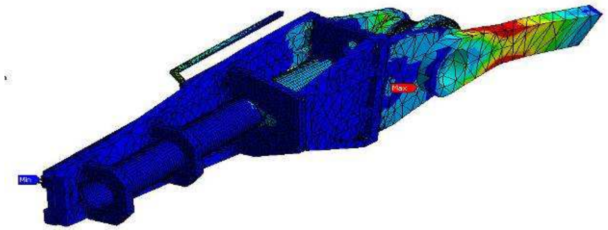
- **On-the-fly data acquisition requirements**

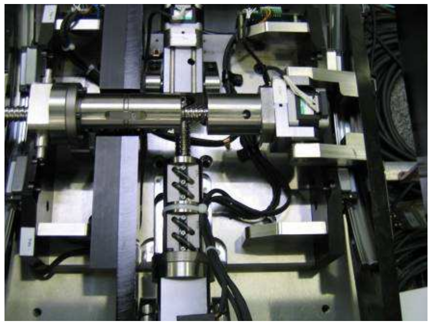
  – On the fly acquisition should be achieved on any multi-axis trajectory or single axis trajectory (PVT mode) and synchronized events:

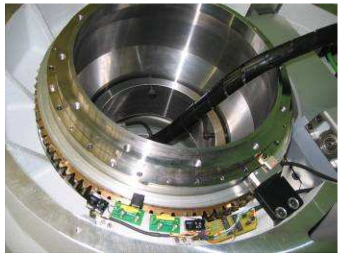
  - Output (related to synchronized signals), controller → detector
    - – output a detector trigger on the motion trajectory at a given encoder position
    - – Time Flasher: output periodic triggering pulses on a complex trajectory (0.4µs)
    - – output a detector trigger one axis at periodic encoder position
  - Input (related to external events) detector → controller
    - Input of external events to trigger all or a selected encoder position and other devices such as detectors
  - Data
    - – Data gathering in real time
    - – Multi-task function and fast data transfer without influence on the motion control

# Fine, fast and coordinated motion and its controls

- On-the-fly acquisition requires dynamics to be present on the mechanical components and on the controller/driver system.
  - **Mechanical:**
    - FEA on structures in view of increasing resonant frequencies and stifness
    - High rigidity bearings
    - Highly preloaded transmissions
    - DC and brushless DC motors
    - High resolution direct mounted encoders

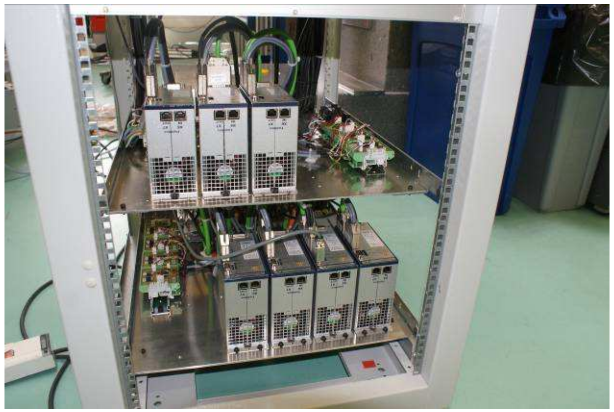


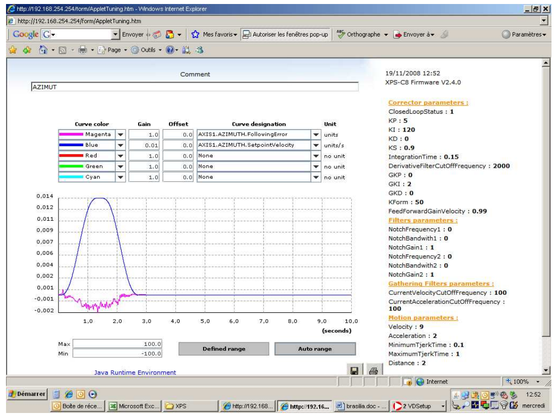




# Fine, fast and coordinated motion and its controls

- **Controller/driver**
  - PVT command set
  - Advance Close loop, FF, PID, Noch filters
  - High speed CPU
  - High speed Ethernet communication
  - Real time mapping capability
  - Multi-task capability





# X-Ray DIFFRACTION ROAD MAP

**Hour**

**PAST:**

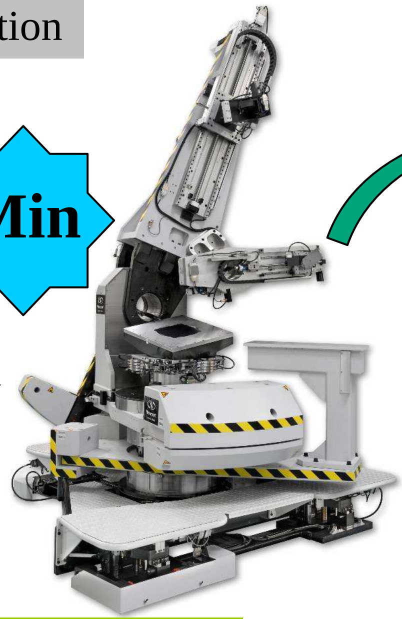
Stepper, Step Scans

Slower communication

**MiM: 0.001°**

**Acc: 0.01°**

**Min**



**MiM: 0.0001°**

**Acc: 0.001°**

**PRESENT:**

DC close loop, On-axis encoders, on-the fly Scans, Trajectories

Ethernet communication

**FUTURE:**

Nanometer knowledge

Nanometer MiM, interferometry

Piezo tech, SiC structures, air-bearings, linear motors

Experience in Semi-Conductor

**MiM: 0.00001°?**

**Acc: 0.0001°?**

**Sec**

(See Dynamyx Platform www.newport.com)

# Conclusion

- All these features have been implemented on our diffractometers and control electronics.
- For a fact, Scans are finer, faster, simpler and of a better quality.
- This is the result of partnership, expertise and years of experience shared with **Dr Rivers** and **Dr Eng** from APS.

# Thank you for your time.